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An Enhanced Genetic Algorithm for Solving Trajectory Planning of Autonomous Robots

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***Abstract*—Different tasks inside the environments call for different types of robots with various traits and designs. The research community appears to favour a number of robot classes in particular area for tackling complex challenges in demanding settings. Important cases of these deployments are examined, and it is determined that high-level autonomy is a crucial problem that has to be solved. It is necessary to drive autonomous mobile robots across the environment to map it, find themselves, and chart out routes between locations. Two crucial capabilities of an autonomous overtaking system are trajectory planning and trajectory tracking, and many approaches have been put forth in the literature for each of these functionalities. However, the majority of the offered approaches are only useful for low-speed overtaking due to ambiguities in environment perception when employing the current generation of sensors. This paper shows an upgraded version of Genetic Algorithm to find the shortest route between the source and destination. In this paper, an upgraded GA is proposed in static environments to solve path planning issues. Numerous studies have offered innovative methods that generate an ideal route using GA. Most of the strategies for generating infeasible pathways ignore the variable length chromosomes. The algorithm converges more quickly because it prevents premature convergence and provides viable pathways with higher fitness values than its parents. The suggested approach is implemented and contrasted in a variety of contexts to demonstrate its validity. The simulation findings demonstrate that, in comparison to previous approaches, utilizing GA with the enhanced operators and the fitness function aids in the discovery of optimal solutions. It is clear from the best optimal solution provided that the proposed UGA outperforms GA. In UGA the execution time is less (15.24s) than the GA that is (19.35s). The proposed model requires less iterations (3127) than the current method (6114), which reduces the total number of iterations. This in turn cuts down on the overall execution time.**

***Keywords*—Autonomous Robots, Upgraded Genetic Algorithm, Trajectory Planning, Distance Matrix**

I. INTRODUCTION

The issues in uncharted situations where human activities are constrained have been addressed by developments in robots. There are many uses for autonomous robots today, including disaster management [1], military operations [2], Mars expeditions [3], self-driving automobiles [4], etc. Most of the time, the system lacks previous knowledge about the trajectory and makeup of the terrain. As a result, the robot must use its internal sensors to learn about its trajectory, the existence of obstacles, the terrain's characteristics, etc. [5]. For instance, a robot sent out on a rescue mission following a landslide must travel through a variety of terrains, including rocks, mud, concrete, etc. [6]. Robot performance may be enhanced by their capacity to comprehend the terrain. Researchers are currently being drawn to the study of autonomous robots in fields like navigation, localization, etc. The main autonomous robot research fields are depicted in Fig. 1. Traditional motion control and path planning techniques presumptively take flat ground and little terrain fluctuations into account. Research on terrain identification issues has improved as a result of advancements in learning approaches and control algorithms [7]. These projects are motivated by research into novel robot system architectures.

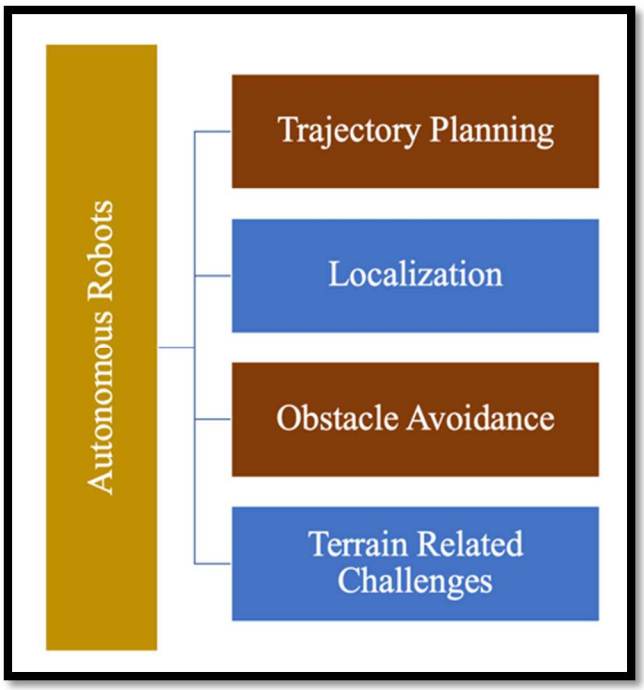

Fig. 1. Autonomous Robots - Research Areas

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Researchers are currently being drawn to the study of autonomous robots in fields like navigation, localization, etc. The main autonomous robot research fields are depicted in Fig. 1. Traditional motion control and path planning techniques presumptively take flat ground and little terrain fluctuations into account. Research on terrain identification issues has improved as a result of advancements in learning approaches and control algorithms [5]. These projects are motivated by research into novel robot system architectures [2]. Using the path as a guide, the robot is able to reach the target condition. It's likely that several pathways can be taken because the robot has so much free movement area. The goal of most path planning algorithms is to find the optimal route, or as close to it as possible. The optimal path is the one that results from minimizing one or more objective optimization functions, and this is what we mean by "best path." For example, this approach may be the most time-efficient one out of the many options available. Search and rescue activities, for example, depend on this since catastrophe victims may seek for aid in life-or-death situations. The robot's energy consumption might be another optimization factor to take into account.

This paper shows a trajectory planning for autonomous robots using an upgraded Genetic Algorithm. The results of the comparison with the conventional genetic algorithm are tabulated. The remainder of the paper concentrates on several works on autonomous robot path planning, the methods employed, and the outcomes of the experiments conducted.

II. Related Works

It is our contention that the use of insect intelligence as a model for tiny, mobile robot autonomy is a viable option [8]. As a resource-efficient species, insects have a distinct edge over other animals, notably in terms of both strength and bulk. Taking a look at where insect-inspired AI is in comparison to other approaches to crucial robotic tasks like as navigation, we find difficulties that still need to be addressed. There are a wide range of materials and structures that may be used in the construction of autonomous robots, but they are not always developed and integrated for multifunctionality [9]. Thanks to recent developments in energy storage technologies, robots may now be fueled by chemical or electrical energy stored in the structures and materials themselves. This paper presents a novel perspective on embodied energy in the context of building autonomous robots. The International Federation of Robotics (IFR) predicts that both service and industrial robot sales will rise [10]. Before autonomous robots may be utilized in the supply chain and logistics industry, a number of requirements must be completed. There are a few management tips for those in charge of supply chains and digital marketing tools in this research.

As a first step in developing autonomous robots, robots must be able to explain their actions to the user was developed in [11]. On the basis of this definition and a survey, we suggest pertinent themes for further research: "What is an explanation?" The cohabitation of autonomous robots and humans requires advanced communication protocols. Various forms of explanations have been considered in the machine learning field, and this study gives an overview of such discussions. The challenge of autonomous vehicle trajectory planning on a curving route is the topic of this research [12]. To deal with the multitude of limitations, an iterative computing approach is provided here.... Our concept is less sensitive to the initial estimate than the previous optimization-based planners, particularly when it is not kinematically possible. Simulations and real-world testing verify the suggested planner's efficacy.

Neurodynamic optimization may be used to design the trajectories of under-actuated autonomous vehicles [13]. A sequential global optimization problem is used to solve a vehicle trajectory planning task with a narrowing horizon. Under the derived assumptions, the formulation of the optimization problem is guaranteed to be feasible. The effectiveness of the neurodynamic-driven trajectory planning technique is shown using simulations involving unmanned wheeled vehicles and autonomous surface vehicles. For all ball-wrist 6DOF (degrees of freedom) [14] manipulators that meet the Piper condition, the paper provides a workable subspace division technique. Single trajectory lines may be used to partition the manipulator joint space into distinct domains having only single inverse kinematic solutions when the Jacobi matrix's determinant is 0. As a result of the nonlinear mapping, each work subspace has only one unique solution, completing the division of the work space. Trajectory planning may be efficiently avoided by picking the inverse kinematic solution in a single working subspace when planning from a single workspace to a region that overlaps with several workspaces. Based on the hybrid optimization techniques for industrial robotic manipulators, a collision-free trajectory is devised (IRMs) [15]. The smoothness of the robot's end-trajectory effector's travel is heavily influenced by kinematic factors such as jerk, acceleration, and velocity. Reduced jerks contribute to smooth robotic action, which improves the endurance of velocity and acceleration.

Using Genetic Approach (GA) [16] optimization, a neural network algorithm has been suggested to design and optimize. The resulting dataset was used to train the BP neural network, which the GA then optimized. Between two nearby important points, an optimized trajectory was demonstrated to have a shorter travel time and a greater speed, both of which contributed to a more successful rehabilitation outcome. Genetic operators RGS, DBX and APCM are added to the INSGA-II [17] to create a new version. Convergence and variety of algorithms are evaluated using inverted generational distance, hypervolume and optimizer overhead. To determine the optimum answer and, thus, the best trajectory, fuzzy comprehensive assessment is applied. The use of a robotic arm in space might significantly boost production and save costs. When operating a system, trajectory planning [18] should be used to prevent significant obstacles.

For welding, assembling, or grinding, intelligent industrial robots must be able to manoeuvre reliably in tight locations with obstacles or work components. Using the usual D-H approach [19], The robot's kinematic model is developed, and the theory of linkage velocity transfer control is discussed. If the robot's route is constrained by many restrictions, an enhanced genetic algorithm may successfully rearrange the path points. Supply chain operations rely heavily on delivery and vehicle scheduling and routing, since both affect distribution costs and customer satisfaction to varying degrees. Among the many VRP variations [20] that logistics and distribution organizations experience on a daily basis, this study proposes a way for categorizing them. There were 334 publications in total, but 263 were devoted to freight transportation when the study approach was used. Moving trucks transport containers [21] that are used as part of the

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Factory-in-a-Box manufacturing idea to install production modules (i.e., factories). The vans travel to the clients' locations and do on-site manufacturing. For vehicle routing, a brand-new multi-objective optimization approach is put out. It's developed using a custom-made hybrid metaheuristic algorithm in mind as a solution method. Data-driven processes need to create place for AI-driven frameworks [22]. The goal of technological advancement is to lessen the amount of network traffic that needs to be managed and the amount of data that needs to be transferred [23]. One of the most recent advancements in short-range wireless networks is the Internet of Things (IoT) [24]. Healthcare databases are made up of various heterogeneous data sources [25].

III. METHODS

In order for a route planner to work properly, it requires input describing the surrounding environment. Depending on the context, this data might represent things like the existence of impediments or certain surface characteristics that are important to the design. It also takes into account how this robot interacts with its surroundings to determine what direction it should take. When minimizing path length, it's sufficient to learn about the locations that can and cannot be crossed, but when reducing energy consumption, it's necessary to consider terra mechanics and the manner the robot steers. In this propped work, we have considered some places of visit through which the trajectory needs to build by the robots. Fig. 2 illustrates the suggested model's total workflow. The locations to be visited are depicted in relation to points as illustrated in Figure 3. The navigation should be in such a way that the route is shortest and also it covers the entire geographic area.

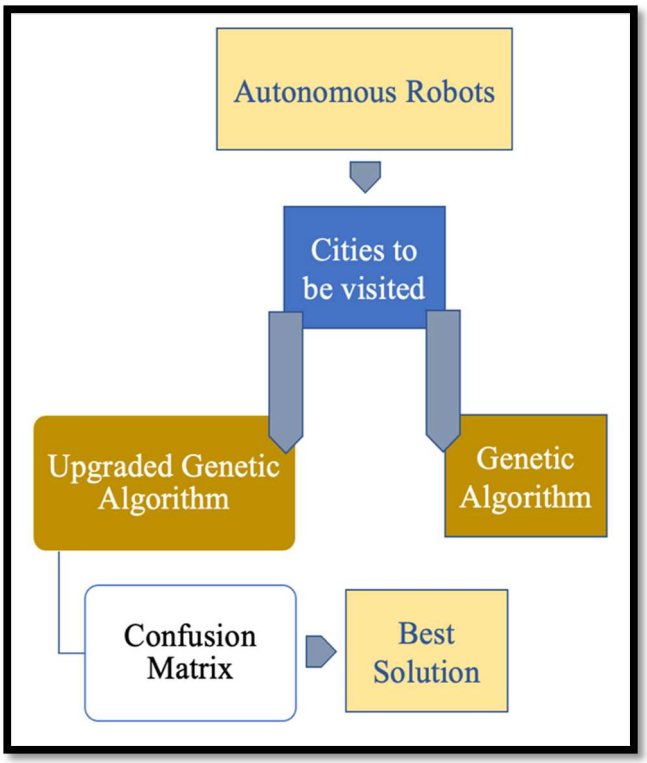

Fig. 2. Trajectory Planning Model

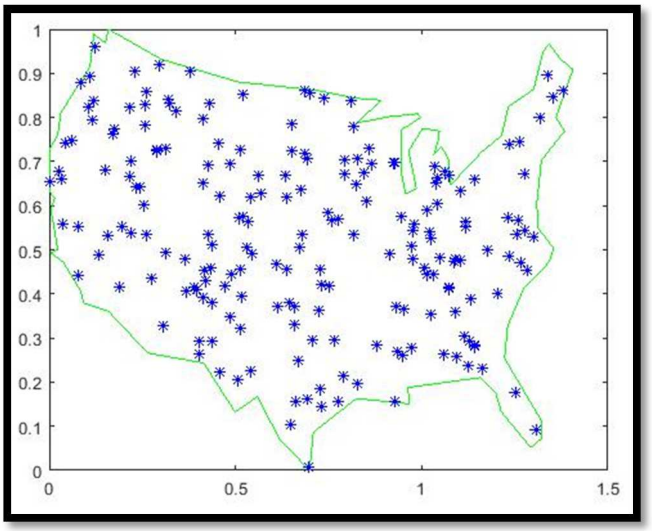

Fig. 3. Places to be visited

Once aware of the cities, must choose the best path. The issue is now referred to as the Trajectory Planning Problem. In this introduced the improved Genetic Algorithm to determine the answer. GA is a problem-solving algorithm that imitates the growth of live creatures by using the same principles as natural selection. Optimization and search difficulties can be solved by using GA. Selection, crossover, and mutation are the most common GA procedures. In the beginning, a random population of people is created and then assessed using the fitness function for each one. According to the set fitness values, the best individuals from the original population will be picked and will participate in the next generation. As the issue evolves, GA's objective function (fitness) becomes more and more critical. It is used to assess individual quality and identify those who will be most valuable to future generations.

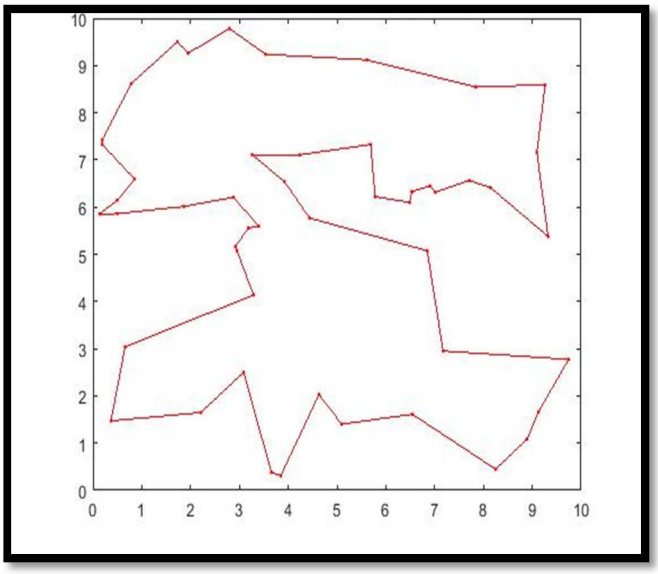

Fig. 4. Trajectory - GA

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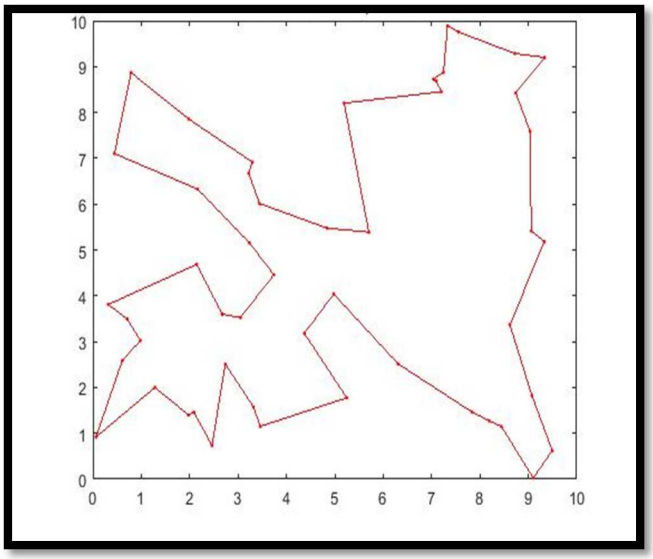

Fig. 5. Trajectory - UGA

The crossover operator generates children by combining the parents' traits and creating new offspring with a mix of the two. New solutions are produced as a result of the mutation operator's random swaps being applied to the new children. As soon as one of the following conditions is met, the algorithm is terminated. The Upgraded Genetic Algorithm (UGA) is created to improve the initial pathways in continuous space and identify the ideal path between the starting and destination locations. In order to enhance the initial routes, the UGA employs five proprietary crossover and mutation operators. As an added bonus, our technique can now handle the path planning problem for several mobile robots. The total distance is obtained while using both GA and UGA and are depicted in the Figs. 4 and 5 respectively.

IV. Results And Discussion

Used Matlab R2017B version and Concorde Solver to demonstrate the effectiveness of the suggested model. As the first step we have to give the places of visit by the robots. They are taken as the position of cities that needs to be visited by the robots. Each city has its own coordinates and they are extracted for further processing. The coordinates are used to find the distance matrix. distance Matrix gives the distance between any two given points on the plane. Once the distance matrix is computed it is fed to the UGA model which will process the given information. The problem is now posed as the trajectory path planning problem is being solved by UGA. We obtain the optimal trajectory with the best solution. Figures 6 and 7 show the plot and the method, respectively. The proposed model was put to the test against the conventional GA, and the results were used to demonstrate its efficacy. The identical procedure is shown in Figs. 8 and 9, respectively. In Table I, a comparison of the outcomes produced by GA and UGA is presented. It is clear from the best optimal solution provided that the proposed UGA outperforms GA. The proposed model requires less iterations than the current method, which reduces the total number of iterations. This in turn cuts down on the overall execution time. In UGA the execution time is less (15.24s) than the GA that is (19.35s). The proposed model requires less iterations (3127) than the current method (6114), which reduces the total number of iterations. This in turn cuts down on the overall execution time. The total distances measured in two different approaches firstly for upgraded genetic algorithm is 56.64 while for the second one genetic algorithm is more 57.17. It is clear from the best optimal solution provided that the proposed UGA outperforms GA.

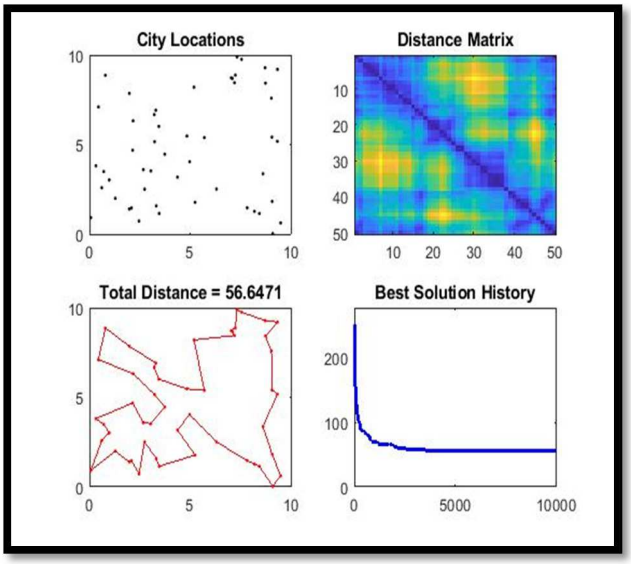

Fig. 6. Optimal Trajectory - UGA

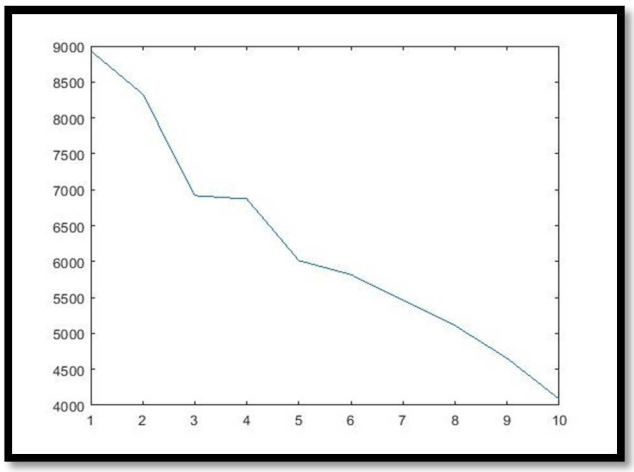

Fig. 7. UGA Iteration Plot

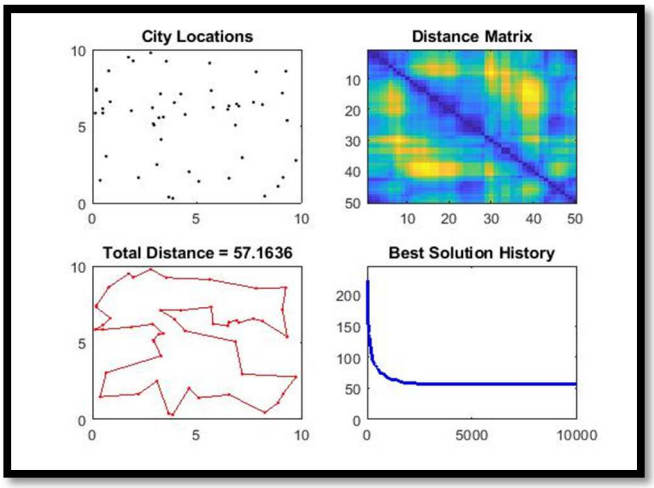

Fig. 8. Optimal Trajectory - GA

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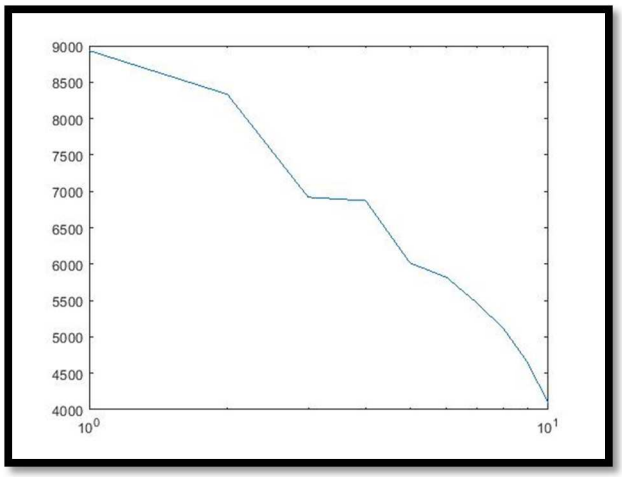

Fig. 9. GA Iteration Plot

TABLE I. EXPERIMENTAL RESULTS

Model	Total Distance	No. of Iterations	Execution Time
Upgraded Genetic Algorithm	56.64	3127	15.24s
Genetic Algorithm	57.17	6114	19.35s

V. CONCLUSIONS

Trajectory planning of robots is one of the most researcher topics across the globe. Evolutionary algorithms benefit greatly from workable beginning solutions, and even when random initial solutions are used, it's possible that they will fail to identify a feasible path after multiple cycles, particularly in big complicated settings. We have made use of the UGA algorithm to verify the effectiveness of our proposed model. According to simulation results, the EGA's control parameters, such as population size and iterations, have little to no effect on how well it performs. Furthermore, limiting the sample size and limiting the number of iterations will lead to better results. Due to the fact that the current study only took into account static barriers, it is recommended that the suggested EGA be extended to include PP in an environment with moving obstacles. Multi-objective optimization can also be employed in place of the weighted linear combination of objectives. As a result, the weights in the objective function will be erased, and the best possible value for all objectives will be achieved at once. Future studies should look at how practical limitations, including those on the robot's speed or steering angle, affect performance.

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